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ADVANCED VEHICLE CONCEPTS SYSTEMS AND DESIGN ANALYSIS STUDIES

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16. Abstract

The work conducted by ELORET Institute under this Cooperative Agreement includes the modeling of hypersonic propulsion systems, and the evaluation of hypersonic vehicles in general and most recently hypersonic waverider vehicles. This work in hypersonics was applied to the design of a two-stage to orbit launch vehicle which was included in the *NASA Access to Space Project.* Additional research regarded the Oblique All-Wing (OAW) Project at NASA Ames and included detailed configuration studies of OAW transport aircraft. Finally, work on the modeling of subsonic and supersonic turbofan engines was conducted under this research program.

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ABSTRACT

The objective for this research program was to develop more sophisticated analysis tools to model the aerodynamic, propulsion, and structural characteristics of vehicles and the dynamics of vehicles in flight. The work conducted by ELORET Institute under this Cooperative Agreement includes the modeling of hypersonic propulsion systems, and the evaluation of hypersonic vehicles in general and most recently hypersonic waverider vehicles. This work in hypersonics was applied to the design of a two-stage to orbit launch vehicle which was included in the *NASA Access to Space Project*. Additional research regarded the Oblique All-Wing (OAW) Project at NASA Ames and included detailed configuration studies of OAW transport aircraft. Finally, work on the modeling of subsonic and supersonic turbofan engines was conducted under this research program.

INTRODUCTION

This research activity has been conducted at the Systems Analysis Branch at NASA Ames Research Center and involves the preliminary design and mission evaluation of advanced vehicle concepts. An advanced vehicle can be any aircraft or spacecraft being proposed within or without NASA. The objective of the work is to conduct vehicle design and mission studies in enough depth so that meaningful comparisons between concepts can be

made and conclusions can be drawn regarding the technical and/or economic viability of a given concept. Typically, several different vehicle concepts may be proposed for a given mission requirement, and a study will emphasize a comparison between concepts.

The objective for this research program was to conduct a major effort in the development of more sophisticated analysis tools to model the aerodynamic, propulsion, and structural characteristics of the vehicles and dynamics of the vehicles in flight. The work conducted by ELORET Institute under this Research Task included the following major topics:

- Hypersonic Propulsion Modeling
- Evaluation of a Hypersonic Waverider Vehicle
- Evaluation of Vehicle Concepts for the NASA Access to Space Project
- Oblique All-Wing (OAW) Transport Aircraft
- Turbofan Engine Modeling
- Propulsion Systems for High Flier Unmanned Aircraft Designs

The following sections report on each of these research topics.

HYPERSONIC PROPULSION MODELING

The development of analytical tools for hypersonic vehicle analysis is a major effort in the Systems Analysis Branch. Work under this Research Task has specifically supported the development of a "Nose-To-Tail" (NTT) propulsion system model for hypersonic

aircraft. Such a program is made difficult because the propulsion system actually involves the aircraft design as well because the vehicle forebody serves as a compression surface for the propulsion system inlet, and the vehicle afterbody serves as an expansion surface for the propulsion system nozzle. Coupled with this is the need to use real gas effects throughout the analysis to account for the reactive properties of air and fuel-air mixtures at high temperature.

Specifically in this Task, programs have been written for the analysis of the vehicle forebody shock field and engine inlet, the engine combustor, and the engine nozzle and vehicle afterbody which serves as the expansion surface for the engine exhaust gas. A graphics program displays a flow path elevation of the complete propulsion system with the associated shock field geometry for each component.

HYPERSONIC WAVERIDER VEHICLE

Under this Research Task, on-going work has supported the design and evaluation of a broad range of vehicle designs and requirements (1,2,3). Most recently, the work has concentrated on an optimized Mach 6 hydrocarbon fuel waverider vehicle. Waveriders are a class of hypersonic vehicles designed to take full advantage of the bow shock generated by the vehicle shape to generate lift at hypersonic speeds. The aerodynamic

shape of such a vehicle is extremely important for good aerodynamic performance, but if other major considerations such as structural weight and propulsion system integration are ignored, a completely impractical vehicle will result.

This Research Task has been part of a specific project to optimize a hydrocarbon fueled waverider designed for Mach 6. A complete synthesis of the vehicle included all aspects of the design and practical constraints. As a result of this analytical project, a waverider vehicle has been defined, and a wind tunnel program is planned to evaluate the low speed characteristics of such a vehicle.

SUPPORT FOR ACCESS TO SPACE PROJECT

An agency wide project to evaluate future candidate launch vehicles to replace the space shuttle took place throughout much of 1993. The Systems Analysis Branch supported the work on this project being done at the NASA Ames Research Center, and in particular work under this Research Program was conducted to model a two stage to orbit (TSTO) launch vehicles. The design has a first stage having airbreathing propulsion and a rocket powered second stage. The airbreathing propulsion is a combination of turbofan engines and ramjets fueled with liquid hydrogen. Takeoff and landing are both horizontal, and the best staging Mach number is approximately 5. The results of this work are very promising, and they were included in the final report presented to NASA Headquarters.

OBLIQUE ALL-WING (OAW) TRANSPORT AIRCRAFT

The OAW program is in its second year with an ultimate goal of a test in the 9'x7' supersonic wind tunnel in May, 1994. The Eloret Institute Principal Investigator of this Research Program has acted as the Co-Leader of this project from its inception at NASA Ames in June, 1992. The work involves approximately 10 people from four different divisions at NASA Ames and contracts with both Boeing Commercial Airplane Company and Douglas Aircraft Company.

The specific work within the Systems Analysis Branch involves the definition and evaluation of a reasonable configuration that would serve as a commercial transport aircraft to carry 450-500 passengers over long range (nominally 5000 N.Mi.) at a flight Mach number of 1.6. The wind tunnel model to be built will be based on this configuration.

The definition and evaluation of the OAW aircraft configuration involves all aspects of airplane design -- structures, weights, propulsion, aerodynamics, and airline economics. Numerous CFD programs are being used to design the wing aerodynamic shape of the wing, and the resulting aerodynamic performance along with the other aspects of the design are modeled in the ACSYNT aircraft synthesis program to simulate the complete

aircraft design and mission performance. Two AIAA conference papers(4,5) have been prepared and were presented in August, 1992. These papers have proven to be a valuable interim step in the definition of an OAW transport aircraft.

TURBOFAN ENGINE MODELING

The long term requirement for this Research Task is to provide propulsion system modeling. To that end there is a major and on-going effort to model subsonic and supersonic turbofan engines for use in the aircraft synthesis programs used in the Branch.

The most direct approach is to use a cycle analysis program developed by an engine manufacturer to produce the basic data. These data for thrust, airflow, and fuel flow are then modeled in a generalized form and integrated in to the synthesis programs. The advantage of this general form is that the data can be scaled to different rated thrust sizes, and the models are sensitive to changes in engine pressure recovery and non-standard day atmospheric conditions.

Most recently, there was a major effort within this research program to have the capability of a basic cycle analysis program within the Branch. The long range goal is to include engine cycle parameters such as compression ratio, turbine inlet temperature, and bypass ratio as parameters in large scale aircraft optimization problems.

The approach being taken is two-fold. First the well known cycle program NEP is being used. This is the NASA Engine Program developed at NASA Lewis Research Center. This program requires the use of fan, compressor, and turbine maps, and separate programs developed by the General Electric Company for NASA Lewis are used for this purpose. Second, a design point program is being written as part of the Research Task. This program computes the detailed turbine cooling requirements of the engine, the geometric flow path through the engine, and the engine weight. The flowpath is used to estimate the weight of each engine component, but it is also important because key data required for input to the turbine map program are generated.

PROPULSION SYSTEMS FOR HIGH FLYER AIRCRAFT DESIGNS

The development of unmanned, high altitude aircraft is an on-going project within the Systems Analysis Branch. These aircraft are referred to as "Platforms", and the objective is to have a means for high altitude atmospheric sampling. The evaluation and modeling of propulsion systems for these high altitude platforms was part of this research program, and most recently the J75-P-13 turbojet engine has been modeled to study the effect of low Reynolds numbers on turbojet engine performance. This is the engine currently used in the U2C high altitude aircraft, and it is rated up to 75000 feet.

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